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Flexural Study of Beam with Web Opening using ANSYS and RSM

[1] Vikas Kumar Sahu, [2]Mr. Shrikant Mishra Sir

[1]Research scholar, [2] Assistant Professor
[1] Department of Civil Engineering,
[1]SSTC, Bhilai, India

Abstract: Due to various architectural and other structural requirements, the beams are required to have web openings. The presence of opening reduces the strength of the beam.The objective of current research is to evaluate the strength of ISMB beam with web opening. The structural durability of beam is evaluated using techniques of FEA. The modelling and FEA simulation is conducted using ANSYS software. From the FEA analysis the structural durability of ISMB beam with rectangular web opening is determined. The critical regions are identified based on higher stresses and strains. The higher deformation is obtained at the zone of web opening. The FEA results have shown that incorporation of web opening reduces the flexural strength of the beam.

***IndexTerms* - Web Openings, Beams**

I. INTRODUCTION

The presence of holes in the webs of steel columns is one of the challenges encountered by designers of steel elements. The openings are necessary for two reasons. The first is to accommodate extensions for air conditioning conduits, sewage and electrical lines, which are at the same level as the steel pillars. The second reason is that the presence of successive apertures reduces the amount of materials required to manufacture the steel webs for cellular beams. In contemporary architectural practices, the integration of a complex system of pipes and ducts is vital to facilitate the provision of essential utilities like as power, water, sewage, electricity, gas, air conditioning, and computer networking. To maintain aesthetic appeal, it is usual practice to position these conduits and pipes under the beam soffit and disguise them with a suspended ceiling, resulting in the creation of a vacant space. By routing these conduits via transverse perforations in the floor timbers, the reduction of wasted space is achieved, resulting in a more compact design. The potential savings may not be considerable for smaller buildings. Nevertheless, even a modest decrease in the height of each floor, when multiplied by the number of floors, can lead to substantial cost reductions for multi-story constructions. These savings can be observed in various aspects such as the overall height of the building, the length of electrical and air conditioning ducts, plumbing risers, walls and partition surfaces, as well as the load on the foundation. The incorporation of holes into beams undeniably provides intricacy to their essential characteristics. The presence of rapid changes in sectional arrangement at opening corners might result in higher stress concentrations, which may ultimately cause ugly and persistent splitting. Moreover, the lower stiffness of a continuous beam might cause a significant redistribution of internal stresses and moments, potentially resulting in excessive bending when subjected to service load. Insufficient provision of additional reinforcement, both in terms of number and level of detail, may significantly undermine the strength and utility of the beam. The many types of small apertures, such as circular, square, or nearly square holes, may be considered as long as their depth (or diameter) inside the beam is proportional to their size in a realistic manner. Specifically, the depth should not exceed 40% of the overall beam depth. In this particular scenario, it may be inferred that beam action would likely result in a triumph. As a result, the procedures involved in investigating and constructing a beam with small openings may bear similarities to those controlling a beam without any openings. However, the presence of apertures disrupts the smooth flow of loads, resulting in the build-up of stress and early fracture at the entry. In order to effectively manage fracture widths and mitigate early beam failure, it is necessary to add a sufficient amount of specialized reinforcement throughout the perimeter of the aperture, as is often required for any kind of discontinuity.

II. LITERATURE REVIEW

Mansur et al. [1] reported that the application of CFRP plates in beam reinforcement resulted in a 7.5% increase in shear-cracking pressures, while the use of non-shrink grout in beam filling led to a 2.5% decrease in such pressures.

Hammad et al. [2] The experimental programme consisted of four beam specimens on a large scale. Every individual sample exhibited a solitary aperture located within the shear zone in proximity to the support. The initial depth constituted 56% of the total depth of the web. The sole factor that influenced the outcome was the nature of the reinforcement. Due to the presence of an aperture in the first beam, which functioned as a benchmark, the second beam was strengthened with horizontal steel bars. Distinct segments of CFRP with unidirectional fibres were utilised to externally reinforce the aperture of the third and fourth beams in their entirety. Furthermore, the incorporation of individual carbon fibre reinforced polymer (CFRP) plies was implemented to enhance the initial chords of both the lower and upper webs.

Tanijaya and Hardjito. [3] conducted study to assess the performance of three T-beams with a hybrid composition comprising reinforced concrete and lightweight concrete. With the exception of the third beam, an aperture of 0.53D was created within the web of each remaining beam, specifically in the zones of low flexural moment-high shear and high flexural moment-shear. The specimens' behaviour was evaluated by assessing the observed reduction in strength, rigidity, and energy dissipation capacity. The test results indicate that the beams containing apertures located in regions of low flexural moment-high shear and high flexural moment experienced a reduction in their ultimate capacity and fracture load by a range of 3% to 10% and 15% to 19%, respectively.

Biswal et al. [4] investigated the behaviour and failure mechanisms of reinforced concrete T-beams with web openings that were reinforced using externally bonded carbon fibre reinforced polymer (CFRP) sheets. A total of eleven full-scale beams, each featuring a solitary circular aperture located at the shear zone, underwent testing. The factors under consideration were the steel stirrups, the ratio of shear span to depth, and the count of CFRP sheets. The experimental findings indicate that the detachment of fiber-reinforced polymer (FRP) sheets took place prior to the occurrence of the fragile shear failure of the reinforced specimens. Nevertheless, the specimens' shear capacities have exhibited an increase ranging from 4.7% to 34.57%. The findings of the tests indicate that the utilisation of CFRP external reinforcement enhances the shear capacity, as determined by test variables such as wrapping techniques, fibre orientations, anchoring techniques, and layer counts.

Oukaili et al. [5] examined the performance of fourteen reinforced concrete T-beams that were equipped with multiple web apertures. The reinforcement method employed in the study involved the use of CFRP fabric. The variables under consideration comprised the quantity of apertures, the loading category, and the approach employed for reinforcing the structural elements at the apertures. Prior to casting the apertures, the researchers encircled the entrances internally with distorted steel rods. The researchers employed CFRP fabric as a reinforcement material when creating apertures in pre-existing timber structures. This study employed three distinct Carbon Fibre Reinforced Polymer (CFRP) fabric arrangements, namely vertical, horizontal, and inclined. The experimental findings revealed that T-beams featuring four and six circular apertures in the unreinforced web, with a diameter equivalent to 48% of the web depth, exhibited a reduction in strength capacity of 30% and 41%, respectively, compared to T-beams without any openings.

Aziz et al. [6] The testing programme employed eight beams that featured circular apertures measuring 62.5% of the width of one side of the flange. Furthermore, the study took into account the influence of cold joints as well as the quantity and positioning of flange apertures. The reference beam was fabricated without any cryogenic connections or apertures. Empirical findings suggest that the shear capacity of a beam that features a single flange opening located at a distance of L/3 from the beam edge undergoes a reduction of roughly 22%. In contrast, the shear capacity of a beam that features a single flange opening located at a distance of L/2 from the beam edge undergoes a reduction of approximately 32%. The reduction in a beam's size is influenced by the location of its flange apertures. Specifically, a beam with two flange apertures located at a distance of L/3 from the beam edge experiences a reduction of approximately 17%, while a beam with two flange openings located at a distance of L/2 from the beam edge experiences a reduction of approximately 39%.

III. OBJECTIVE

The objective of current research is to evaluate the strength of ISMB beam with web opening. The structural durability of beam is evaluated using techniques of FEA. The modelling and FEA simulation is conducted using ANSYS software.

IV. METHODOLOGY

For conducting structural analysis, the ANSYS FEA simulation tool is used. The FEA analysis is conducted using different steps. In the 1st step the model is developed in design modeler.

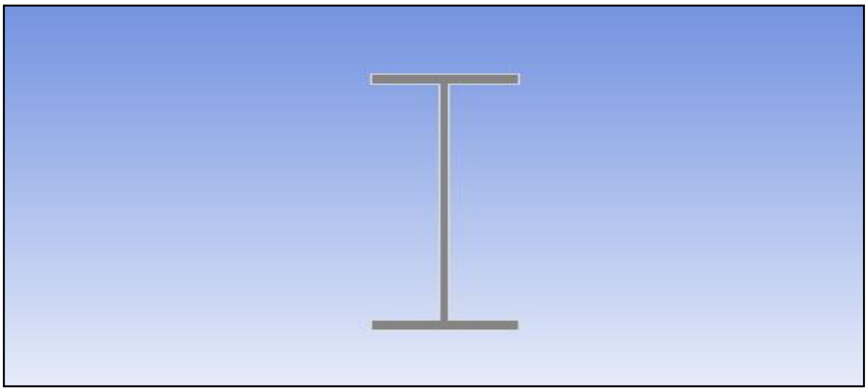

Figure 1: Side view of ISMB beam

The model of ISMB beam is developed using sketch and extrude tool. The developed model of ISMB beam is shown in figure 1. The side view and front view of ISMB beam is shown in figure 1 and figure 2.

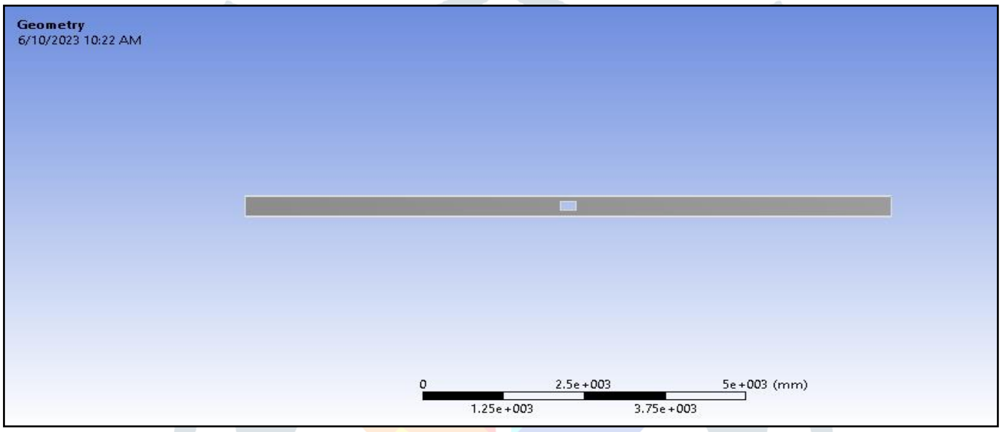

Figure 2: Front view of ISMB beam

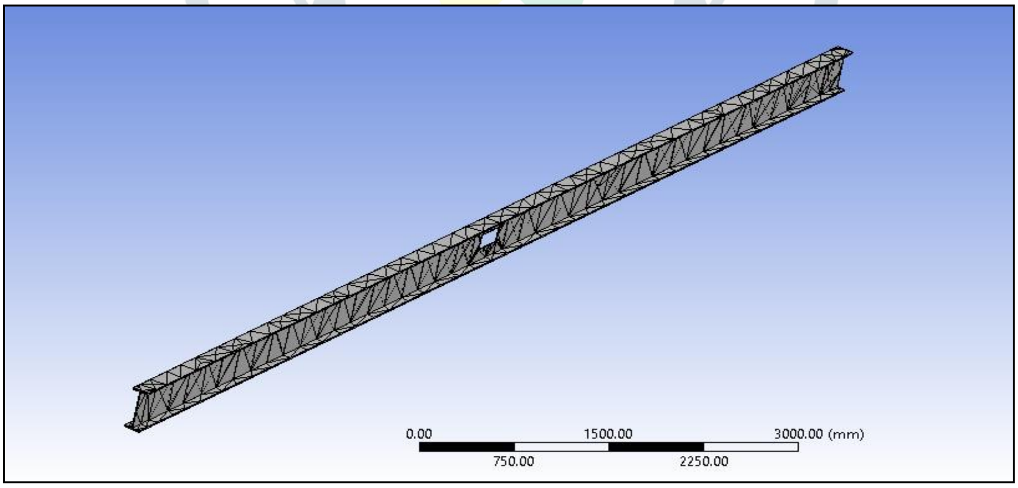

Figure 3: Meshed model of ISMB beam

The ISMB beam model is discretized using tetrahedral element type. The tetrahedral element is selected due to topological inconsistency. The fine sizing meshing is selected with normal inflation.

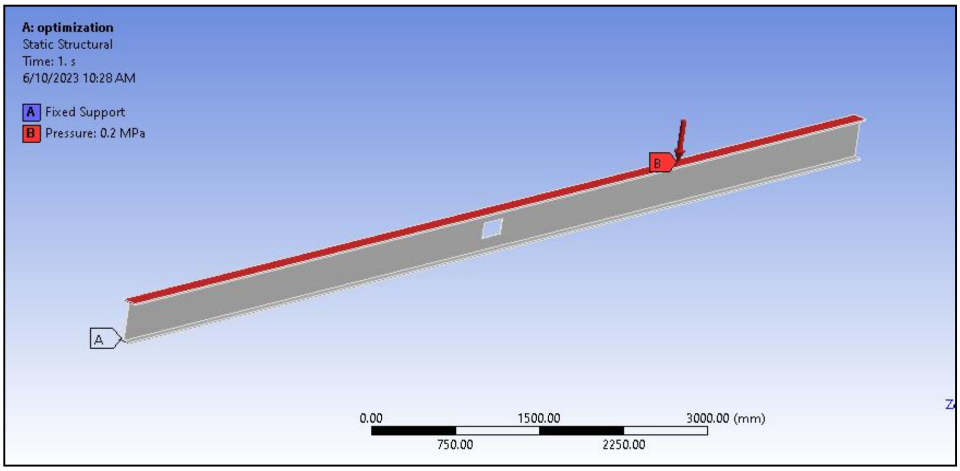

Figure 4: Structural loads on beam

The structural loads and boundary conditions are applied on the beam. The structural boundary conditions involve applying support and loads. The fixed support is applied at the base of the beam. After applying boundary conditions, the simulation is run as per standard solver settings. From the simulation the nodal displacement and strain values are obtained.

V. RESULTS AND DISCUSSION

The FEA simulation is run to determine the structural stability of beams. The principal elastic strain is higher at the support regions wherein the magnitude is .000826mm/mm. The strain is lower at various regions of beam wherein the magnitude is .000013mm/mm.

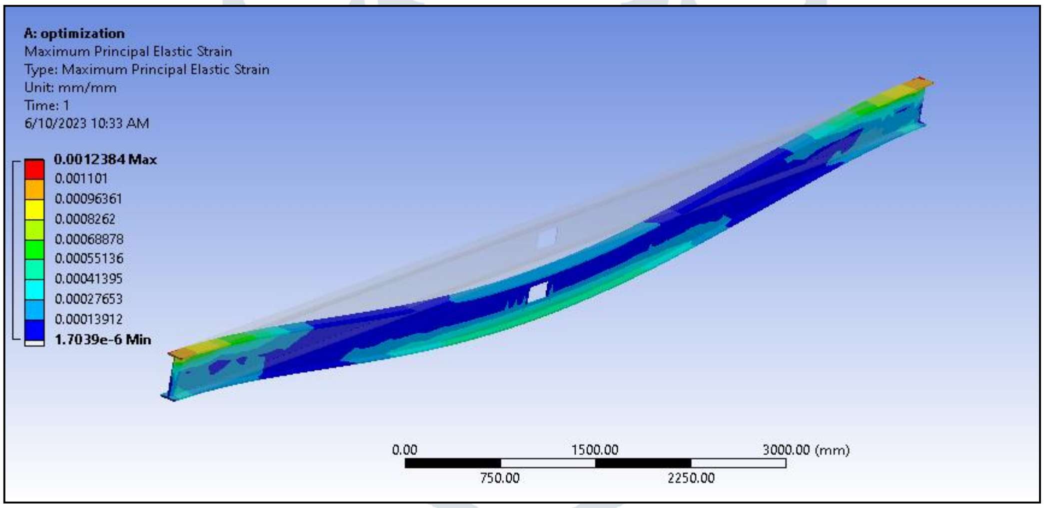

Figure 5: Principal elastic strain plot

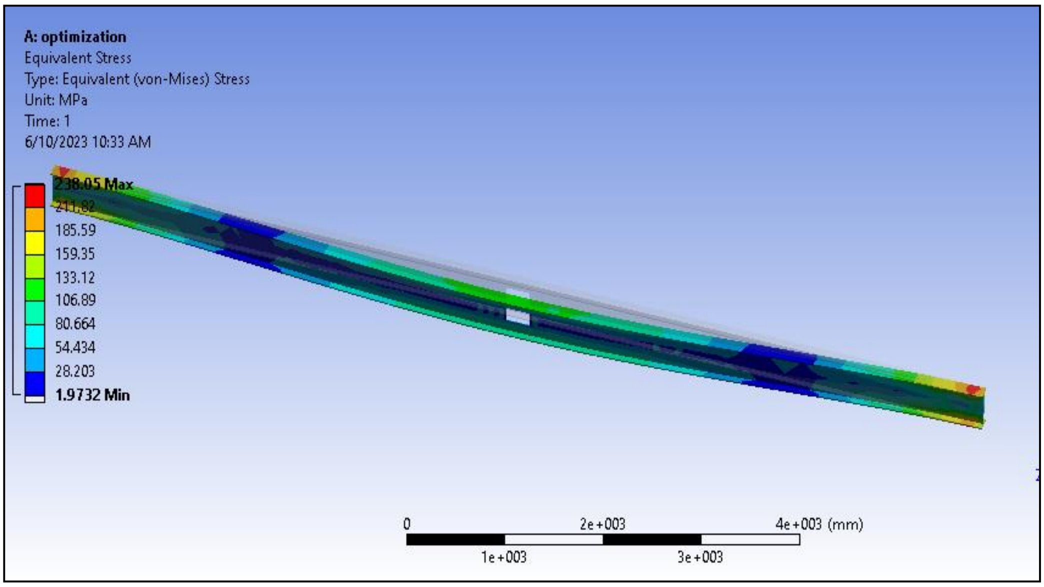

Figure 6: Equivalent stress distribution plot

The equivalent stress distribution plot is obtained for ISMB beam. The equivalent stress distribution shows non uniform magnitude at different regions. The equivalent stress is higher at the support regions. The equivalent stress at blue colored zone is 28.2MPa. The equivalent stress at the mid-section zone of the beam is nearly 130MPa.

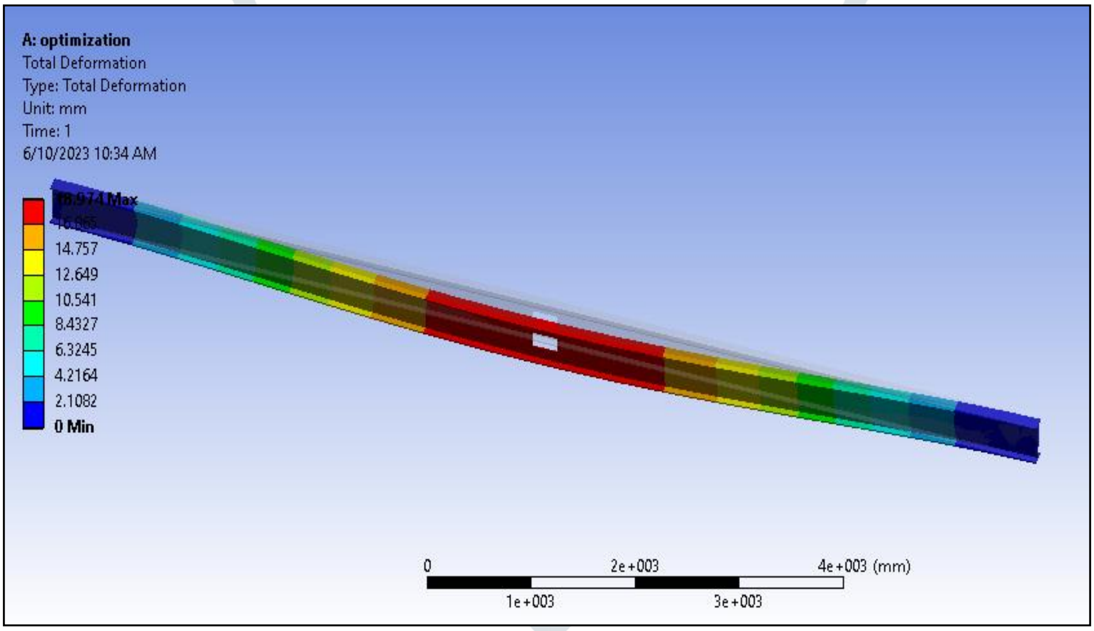

Figure 7: Total Deformation plot

From the structural analysis, the total deformation plot is obtained for the ISMB beam. The total deformation is maximum at the center of the beam. The deformation reduces along the length of the beam. The deformation at the center of the beam is 16.8mm and deformation at the support regions is nearly 12.6mm.

VI. CONCLUSION

From the FEA analysis the structural durability of ISMB beam with rectangular web opening is determined. The critical regions are identified based on higher stresses and strains. The higher deformation is obtained at the zone of web opening. The FEA results have shown that incorporation of web opening reduces the flexural strength of the beam.

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